APPENDIX 14C – DOSE ESTIMATES

TABLE OF CONTENTS

SECTION	TITLE
1.0	DOSE ESTIMATES
1.1	DOSE CALCULATION PROCEDURES
2.0	CALCULATION OF ACTIVITY RELEASED DURING THE ACCIDENT
2.1	ACTIVITY RELEASED DURING CONTAINMENT BUILDING LEAKAGE
2.2	ACTIVITY RELEASED DURING ESF LEAKAGE TO THE AUXILIARY BUILDING
2.3	ACTIVITY RELEASED DURING ESF LEAKAGE TO THE BWST
3.0	DOSE RESULTS
4.0	REFERENCES

LIST OF TABLES

TABLE	TITLE
14C-1	ASSUMPTIONS USED FOR DOSE CALCULATIONS
14C-2	ASSUMPTIONS FOR DOSE CALCULATIONS

APPENDIX 14C

EVALUATION OF ACCIDENT DOSE

1.0 DOSE ESTIMATES

Thyroid dose is not required for the MHA (LOCA) and fuel handling accident in containment (FHAIC) based on the implementation of Alternative Source Term (AST) per Regulatory Guide 1.183 and 10CFR50.67. For these accidents, TEDE doses for the Control Room (CR), Exclusion Area Boundary (EAB), and Low Population Zone (LPZ) were calculated using the NRC-sponsored computer code RADTRAD. Exelon Calculation C-1101-900-E000-087 (Ref. 3) describes this in detail. The formulas for the calculation are contained in NUREG/CR-6604.

The Maximum Hypothetical Accident (MHA) is the postulation of a gross release of fission products to the reactor building. The release is not mechanistic and a means for it to occur is not postulated. The intent of the analysis is to demonstrate the ability of the containment and other plant systems to minimize gross releases of radioactivity and limit the resulting offsite dose. Thyroid and whole body doses have previously been computed for the MHA at TMI-1. These calculations included dose contributions for Containment Building leakage, ESF leakage to the Auxiliary Building, and ESF Leakage to the Borated Water Storage Tank (BWST). The calculations were made for the 2 hour dose at the exclusion area boundary (EAB), and for the 30 day dose at the low population zone boundary (LPZ). The acceptance criteria for that analysis had been the offsite doses specified in 10CFR100.

The control room, EAB, and LPZ doses calculated using the AST methodology include contributions from:

1) Containment leakage,
2) ESF leakage,
3) Leakage from the BWST,
4) Containment purge,
5) Containment shine,
6) External cloud shine, and
7) Control room filter shine.

The containment leakage path is analyzed with the following containment spray operations:

Two spray pumps operate from t=75 sec to t=29.44 minutes and one spray pump operates from t=29.44 to 240 minutes in the sump recirc mode. Spray flow during both periods is at a flow rate of 800 gpm per pump. The BWST depletion time is conservatively estimated at t=29.44 minutes. This corresponds to two spray pumps operating at 1,250 gpm each. This is conservative since faster depletion of the BWST causes ESF leakage to start earlier. The assumption of only one pump running in the sump recirculation mode is conservative.

The above release paths were analyzed with the following assumptions to demonstrate additional conservatisms in the AST analysis:

1. The containment isolation time is extended to 1.0 minute and a more conservative RCS Dose Equivalent I-131 activity of 1.0 μCi/g was used.

2. The unfiltered containment purge activity (during item 1 above) is released directly to the environment.
3. The CR unfiltered inleakage is assumed to be 1,000 cfm. Testing has measured this leakage as 233 +/- 129 cfm.
4. The CR Emergency Ventilation (CREV) system is assumed to initiate at 30 minutes after a LOCA. This assumes a manual operator action for isolation and initiation.
5. BWST depletion time is conservatively assumed at 28.19 minutes corresponding to two spray pumps operating at 1,250 gpm. The actual depletion time would be longer due to an assumed 800 gpm per pump flow rate.

The most limiting 2-hr maximum EAB dose is, by far, due to the containment leakage. This period starts at 0.8 hrs. and ends at 2.8 hrs. A total of 20.674 Rem TEDE due to containment leakage is received during this period.

The inventory of fission products in the reactor core and available for release to the containment is based on the maximum power level of 2,619 MWt corresponding to current fuel enrichment and fuel burnup, which is 1.02 times the current licensed rated thermal power of 2,568 MWt.

The core inventory release fractions, by radionuclide groups, for the gap release and early in-vessel damage states for DBA LOCA are specified in Regulatory Guide 1.183.

The TMI-1 minimum containment sump pH resulting from the radiolysis of the chloride base hypalon insulation inside containment, which produces hydrochloric acid (HCl) was evaluated. The estimated quantity of hypalon in the cable was doubled to calculate a minimum sump pH of 7.3. Therefore, the TMI-1 sump pH meets the regulatory pH requirement of >7.

The radioactivity released from the fuel is assumed to mix instantaneously and homogeneously throughout the free air volume of the primary containment. Fifty seven percent (57%) of the released activity is distributed in the sprayed region and 43% of activity in the unsprayed region based on their respective volumes The sprayed and unsprayed volumes previously used (67% and 33% respectively) are adjusted to account for the reduction in building spray flow.

Reduction in airborne radioactivity in the containment by natural deposition within the containment is credited using the RADTRAD Powers model for aerosols with the removal coefficient of 10-percentile probability.

The primary containment is assumed to leak at the technical specification peak pressure leak rate for the first 24 hours and 50% of TS leak rate after the first 24 hours.

The TMI-1 CR emergency filtration system is conservatively assumed to isolate and initiate at 30 minutes after a LOCA. During this 30-minute period, although the normal ventilation fans are not operating, one half of the design flow rate is assumed (unfiltered) per SRP 6.4. This is a conservative value for air intake considering that no fans will be running during this time.

The single active component failures such as the operation of one fan cooler with reduced air flow and initiation of two spray trains (aligned to the BWST) to initiate the ESF leakage earlier are assumed to maximize the radiological consequences. Assumptions regarding the occurrence and timing of a loss of offsite power are selected for the CREV system with the objective of maximizing the postulated radiological consequences.

1.1 DOSE CALCULATION PROCEDURES

1.1.1 TEDE Dose Calculation Methodology

TEDE doses are computed using the NRC-sponsored computer code RADTRAD and documented in Ref. 3.

Breathing Rates for the hypothetical individual at the EAB or LPZ are as follows (m^3/sec):

Time Period	Breathing Rate
0 – 8 hours	3.5E-4
8 – 24 hours	1.8E-4
24 – 720 hours	2.3E-4

Breathing Rate for individuals in the control room is (m^3/sec):

Time Period	Breathing Rate
0 – 720 hours	3.5×10^{-4}

2.0 CALCULATION OF ACTIVITY RELEASED DURING THE ACCIDENT

2.1 Activity Released During Containment Building Leakage

The initial amount of each iodine form (elemental, particulate or organic) in the containment building available for release is based on the assumptions of Regulatory Guide 1.183. This assumption is that 95% of the core iodine inventory is released into the containment building is in the form of particulate, 4.85% elemental, and 0.15% organic.

A two-compartment model is used to calculate spray iodine removal in the containment since the spray droplets do not reach certain areas. Mixing between the sprayed and unsprayed volumes is assumed to be only that provided by the reactor building air-cooling units. The RADTRAD code accounts for this mixing.

2.2 Activity Released During ESF Leakage to the Auxiliary Building

The offsite dose consequences of ESF leakage are dependent on the iodine activity in the coolant being recirculated. The core inventory of iodine is obtained from Table 14.2-4. The volume of coolant in the Reactor Building consists of the volume of water pumped from the BWST and sodium hydroxide tanks, the volume released from the core flood tanks, and the water originally present in the reactor coolant. When sump recirculation begins, this coolant is assumed to leak into the Auxiliary Building at a rate of 30 gallons per hour, twice the leakage limit of Technical Specification 4.5.4. Once this leakage enters the building, some fraction of the iodine in the coolant goes airborne in the building and is ultimately released to the environment. This was agreed on by the NRC staff based on the temperature profile of the sump water.

Interval	Flashing Fraction
0 – 24 hours	5%
24 – 720 hours	2%

$$\frac{dQic}{dt} = -(Qic)\left(\lambda_{Ri} + \frac{L_a}{V_c} + \frac{L_b}{V_c}\right)$$

$$R_i = (Q_{ic})\left(\frac{L_a}{V_c}\right)(F)$$

2.3 Activity Released During ESF Leakage to the BWST

The source of leakage to the BWST is the same coolant that is the source of ESF to the Auxiliary Building leakage. When sump recirculation begins, this coolant is initially assumed to leak to the BWST at a rate of 3 gallons per minute. After five hours the leak is reduced to 1.7 gpm, and after 24 hours it is reduced to 1.6 gpm. Once this leakage enters the tank, some fraction of the iodine in the coolant goes airborne into the air space of the tank. Consistent with similar ESF leakage assumptions in the USNRC Standard Review Plan, it is assumed that 10% of this iodine goes airborne in the empty space of the tank. The empty space in the tank is assumed to be at least 300,000 gallons, based on the minimum volume that would be pumped from the BWST before sump recirculation begins. This airborne activity is then displaced from the tank at a volumetric rate that is equal to the volumetric rate of water leaking into the tank.

$$\frac{dQ_{ic}}{dt} = -(Q_{ic})\left(\lambda_{Ri} + \frac{L_a}{V_c} + \frac{L_b}{V_c}\right)$$

$$d\,\frac{Q_{ib}}{dt} = (Q_{ic})\left(\frac{L_b}{V_c}\right) - (Q_{ib})\left(\frac{R_b}{V_b}\right)$$

3.0 DOSE RESULTS

Post-LOCA Activity Release Path	Post-LOCA TEDE Dose (Rem) Receptor Location		
	Control Room	EAB *	LPZ
Containment Leakage	6.6319E-01	2.0674E+01	5.8032E+00
ESF Leakage	4.0598E+00	2.6167E+00	1.9063E+00
BWST Leakage	3.6730E-02	3.0611E-02	4.4566E-02
Cont. Purge	3.5503E-03	2.6343E-02	4.6495E-03
Containment Shine	0.0000E+00	0.0000E+00	0.0000E+00
External Cloud	0.0000E+00	0.0000E+00	0.0000E+00
CR Filter Shine	1.326E-02	0.0000E+00	0.0000E+00
Total	4.7765E+00	2.3347E+01	7.7587E+00
Allowable TEDE Limit	5.0000E+00	2.5000E+01	2.5000E+01

* This period starts at 0.8 hrs. and ends at 2.8 hrs.

4.0 REFERENCES

1. Deleted

2. Polestar Calculation No. PSAT 05656A.04, Rev. 0A, “Calculation of TMI-1 Engineered Safety Feature Component Leakage Iodine Release.”

3. AmerGen Calculation C-1101-900-E000-087, Rev. 3, “Post-LOCA EAB, LPZ, TSC, and CR Doses Using AST and RG 1.183 Requirements.”

TABLE 14C-1
(Sheet 1 of 1)
ASSUMPTIONS USED FOR DOSE CALCULATIONS

Time periods	
EAB	2 hours
LPZ	30 days
Average atmospheric diffusion factors, X/Q	
0 – 2 hour EAB	8.0×10^{-4} sec/m^3
0 – 2 hour LPZ	1.4×10^{-4} sec/m^3
2 – 8 hour LPZ	6.0×10^{-5} sec/m^3
8 – 24 hour LPZ	3.9×10^{-5} sec/m^3
24 – 96 hour LPZ	1.6×10^{-5} sec/m^3
96 – 720 hour LPZ	4.0×10^{-6} sec/m^3
Power level, P_o	2568 MW (Note 1)
Containment leakage rate, L	0.1%/day (Note 2)
Spray removal coefficients, λ_i	see Table 14B-3
Total containment free volume, V_c	2.16×10^6 ft^3
Containment Building sprayed volume, V_s	1.23×10^6 ft^3
Mixed flow between sprayed and unsprayed Volumes, F_A, two fans operating	58,000 ft^3/min
Time to sump recirculation	28.5 min
Recirculating sump coolant volume	54,519 ft^3
BWST air volume	40,123 ft^3

1 The core inventories in Table 14.2-4 were deliberately multiplied by 1.1 for conservatism.
2 Reduced to half this rate after 24 hours.

TABLE 14C-2
(Sheet 1 of 1)

ASSUMPTIONS FOR DOSE CALCULATIONS

	Half Life (hr)	Curies in Core Per MWt	Average Gamma Energy (MeV/dis)	Thyroid Dose Conversion Factor (Rem/Ci)
KR-83M	1.83E+00	3.97E+03	2.60E-03	N/A
KR-85M	4.39E+00	9.35E+03	1.58E-01	N/A
KR-85	9.48E+04	2.70E+02	2.23E-03	N/A
KR-87	1.27E+00	1.71E+04	7.92E-01	N/A
KR-88	2.80E+00	2.39E+04	1.95E+00	N/A
XE-131M	2.83E+02	1.90E+02	2.01E-02	N/A
XE-133M	5.42E+01	1.32E+03	4.16E-02	N/A
XE-133	1.27E+02	5.45E+04	4.52E-02	N/A
XE-135M	2.60E-01	1.41E+04	4.32E-01	N/A
XE-135	9.17+00	9.35E+03	2.49E-01	N/A
Xe-138	2.40E-01	5.02E+04	1.13E+00	N/A
I-131	1.93E+02	3.18E+04	3.81E-01	1.08E+06
I-132	2.33E+00	3.71E+04	2.29E+00	6.44E+03
I-133	2.09E+01	5.49E+04	6.08E-01	1.80E+05
I-134	8.63E-01	6.89E+04	2.63E+00	1.07E+03
I-135	6.73E+00	5.45E+04	1.58E+00	3.13E+04